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Hu et al.

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(54) **INFRARED DETECTOR**

(75) Inventors: **Chun-Hua Hu**, Beijing (CN); **Chang-Hong Liu**, Beijing (CN); **Shou-Shan Fan**, Beijing (CN)

(73) Assignees: **Tsinghua University**, Beijing (CN); **HON HAI PRECISION INDUSTRY CO., LTD.**, New Taipei (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1123 days.

This patent is subject to a terminal disclaimer.

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G01J 5/12	(2006.01)
G01J 5/14	(2006.01)
G01J 5/04	(2006.01)
B82Y 30/00	(2011.01)
H01L 51/00	(2006.01)
H01L 51/44	(2006.01)
H01L 31/0256	(2006.01)
G01J 5/02	(2006.01)

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CPC ***G01J 5/16*** (2013.01); ***B82Y 30/00*** (2013.01); ***G01J 5/023*** (2013.01); ***G01J 5/048*** (2013.01); ***G01J 5/12*** (2013.01); ***G01J 5/14*** (2013.01); ***H01L 51/0048*** (2013.01); ***H01L 51/441*** (2013.01); ***H01L 51/448*** (2013.01); *G01J 1/1626* (2013.01); *G01J 5/02* (2013.01); *G01J 5/04* (2013.01); *G01J 2005/065* (2013.01); *G01J 2005/068* (2013.01); *G01N 2201/022* (2013.01); *H01L 35/32* (2013.01); *H01L 2031/0344* (2013.01)

(58) **Field of Classification Search**
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USPC 250/353, 338.1, 338.3
See application file for complete search history.

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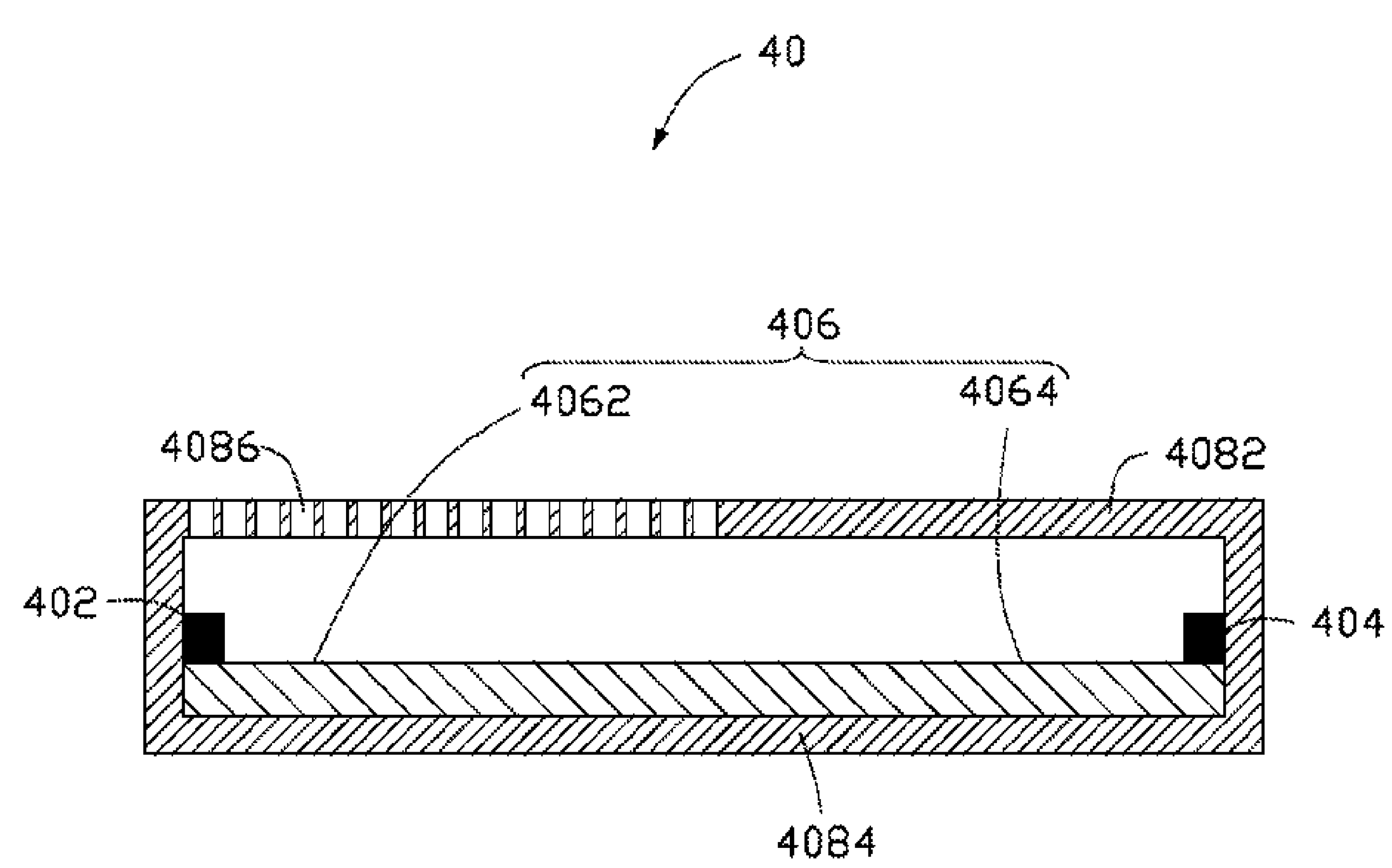
Primary Examiner — David Porta
Assistant Examiner — Carolyn Igyarto
(74) *Attorney, Agent, or Firm* — Zhigang Ma

(57) **ABSTRACT**

An infrared detector includes a detecting element, a first electrode, a second electrode, and a covering structure. The detecting element defines an absorbing part and a non-absorbing part. The detecting element includes a first end and a second end opposite with the first end. The first end is disposed in the absorbing part. The second end is disposed in the non-absorbing part. The first electrode is electrically connected with the first end. The second electrode is electrically connected with the second end. The covering structure covers the non-absorbing part. The detecting element further includes a carbon nanotube layer. The carbon nanotube layer includes a plurality of carbon nanotubes disposed uniformly.

11 Claims, 15 Drawing Sheets



(51) **Int. Cl.**

H01L 35/32	(2006.01)
G01J 5/06	(2006.01)
G01J 1/16	(2006.01)

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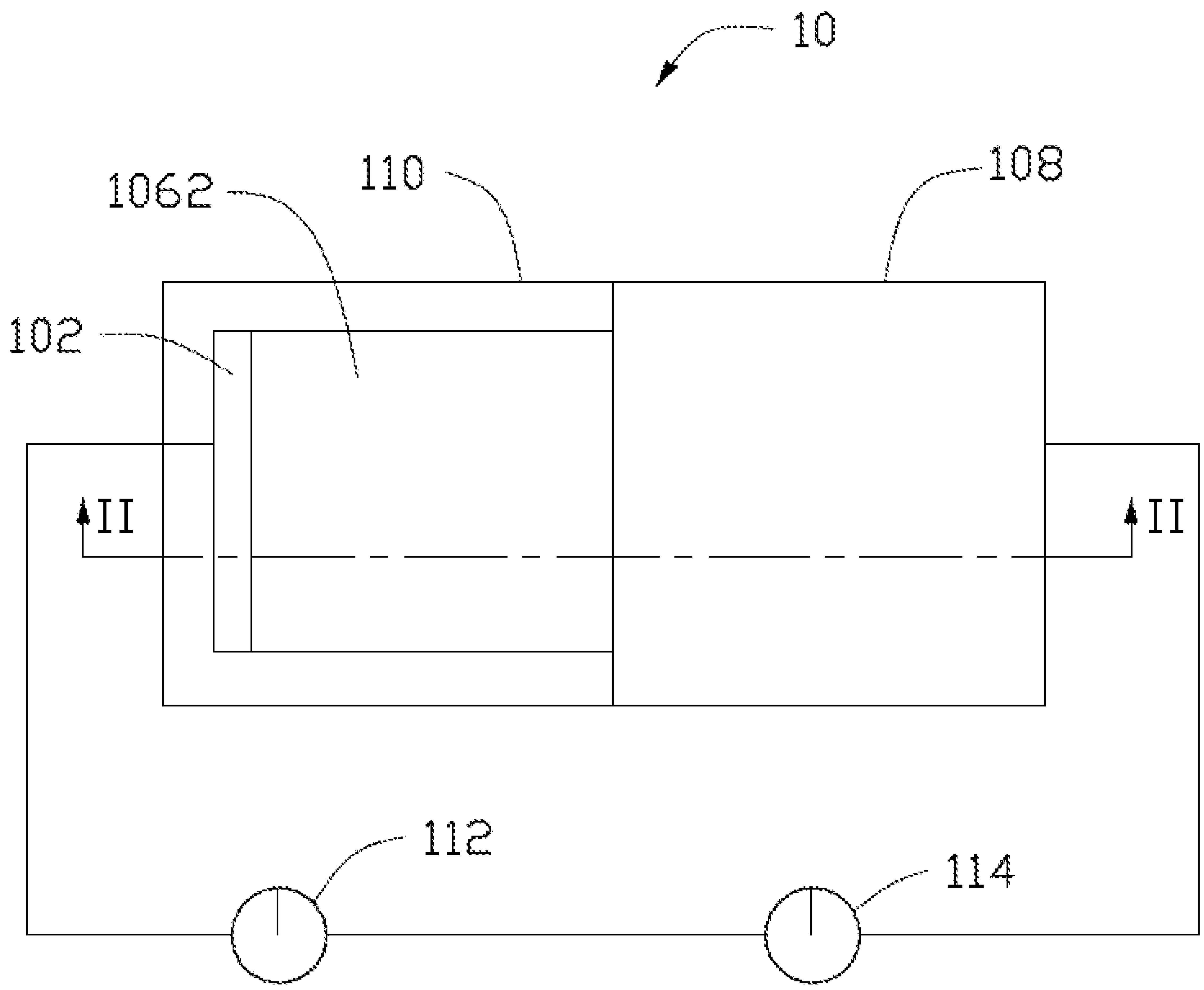

FIG. 1

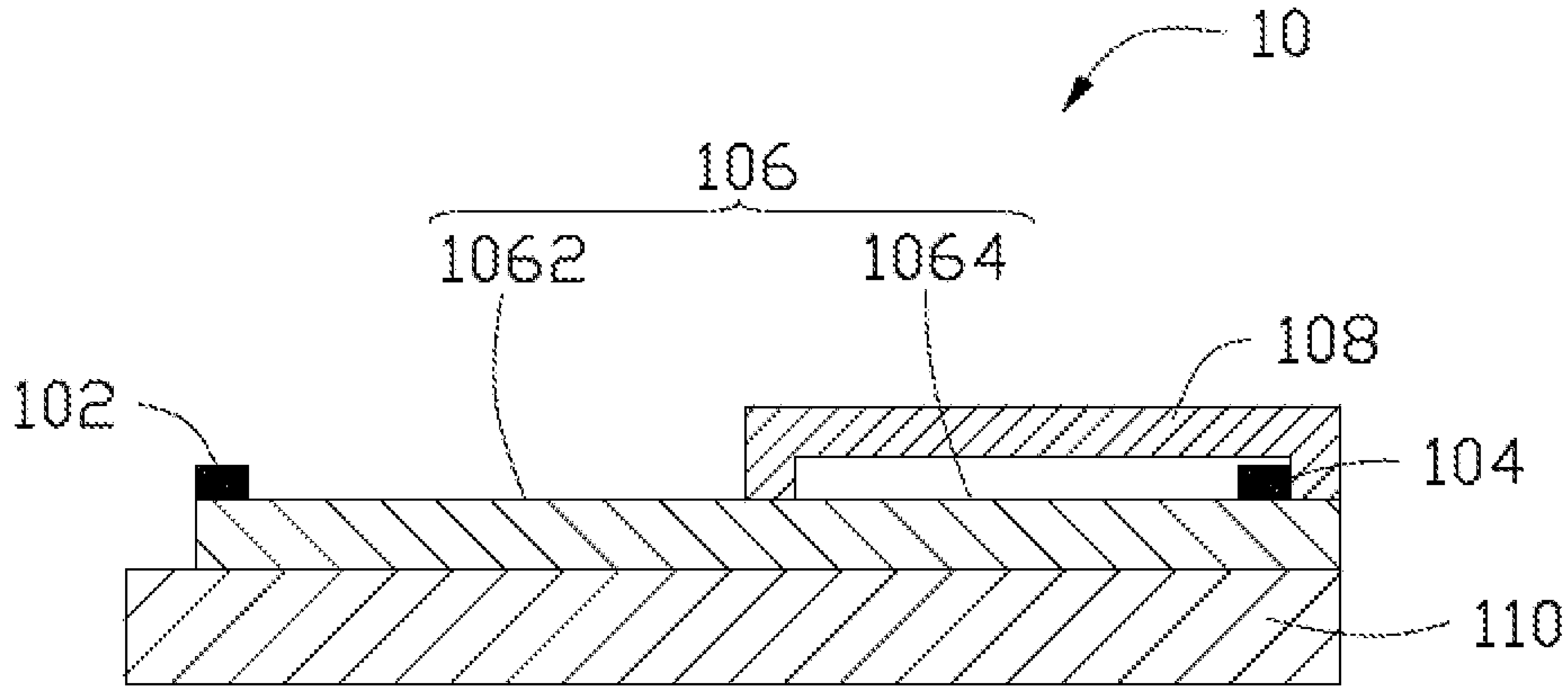

FIG. 2

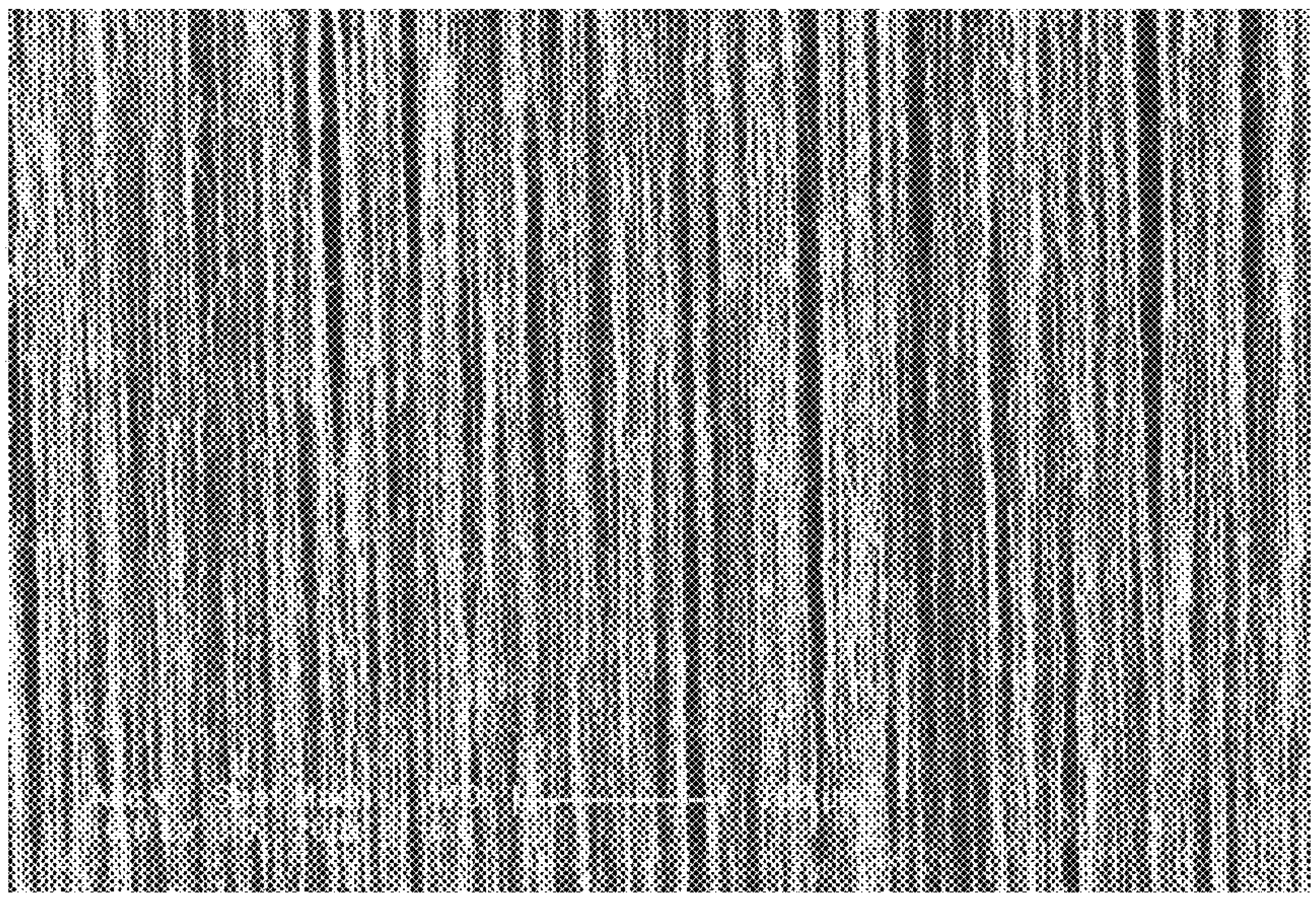

FIG. 2A

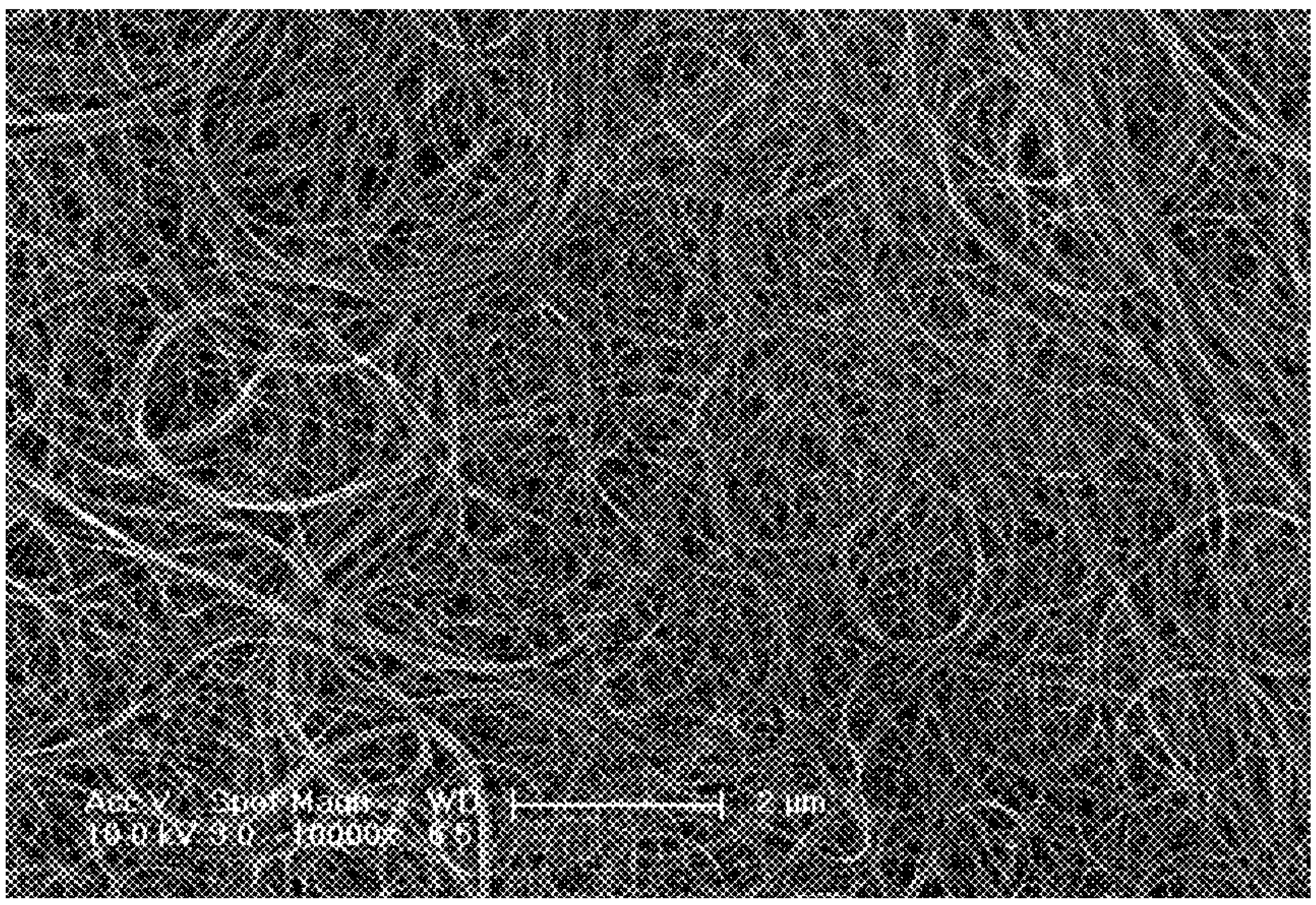

FIG. 2B

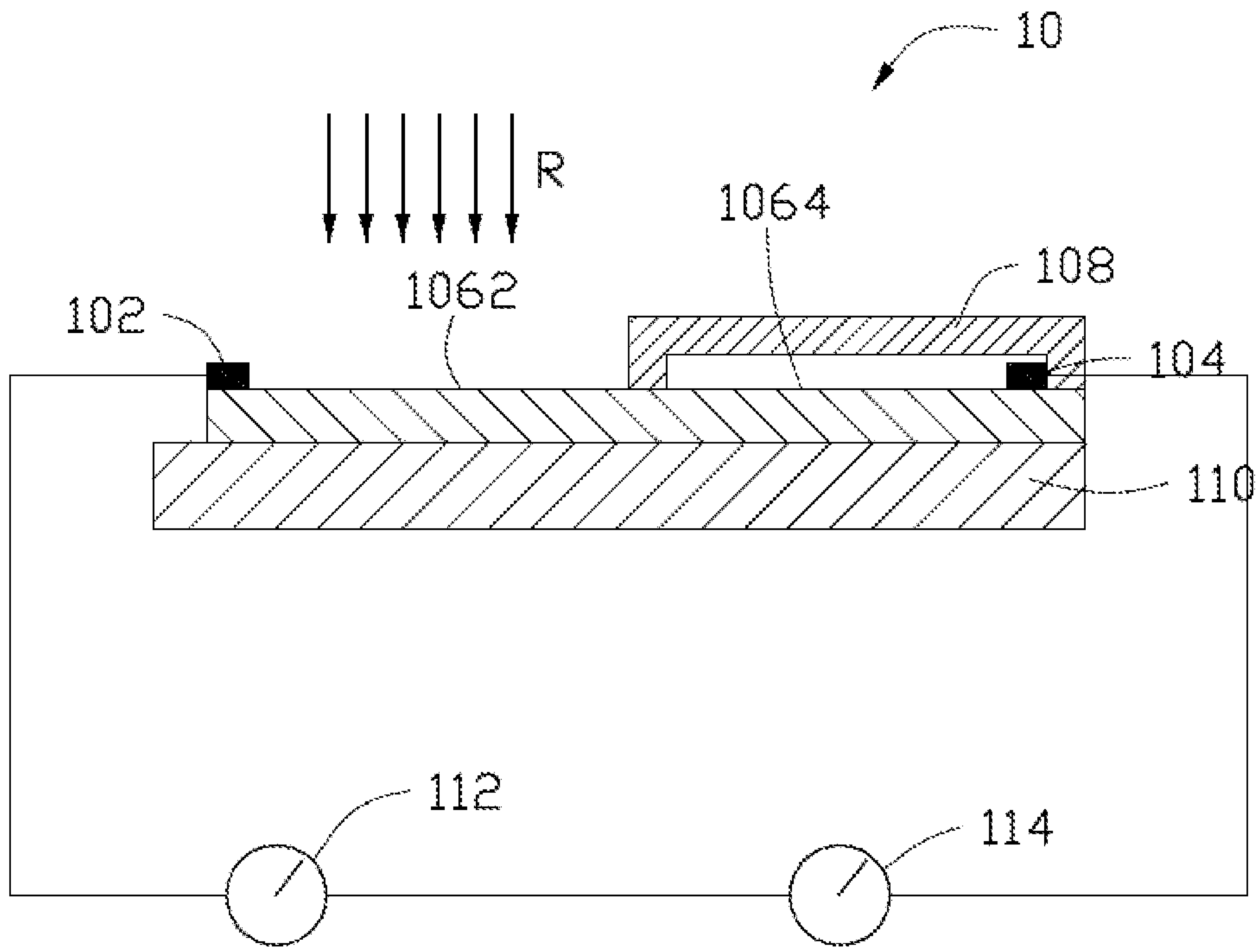

FIG. 3

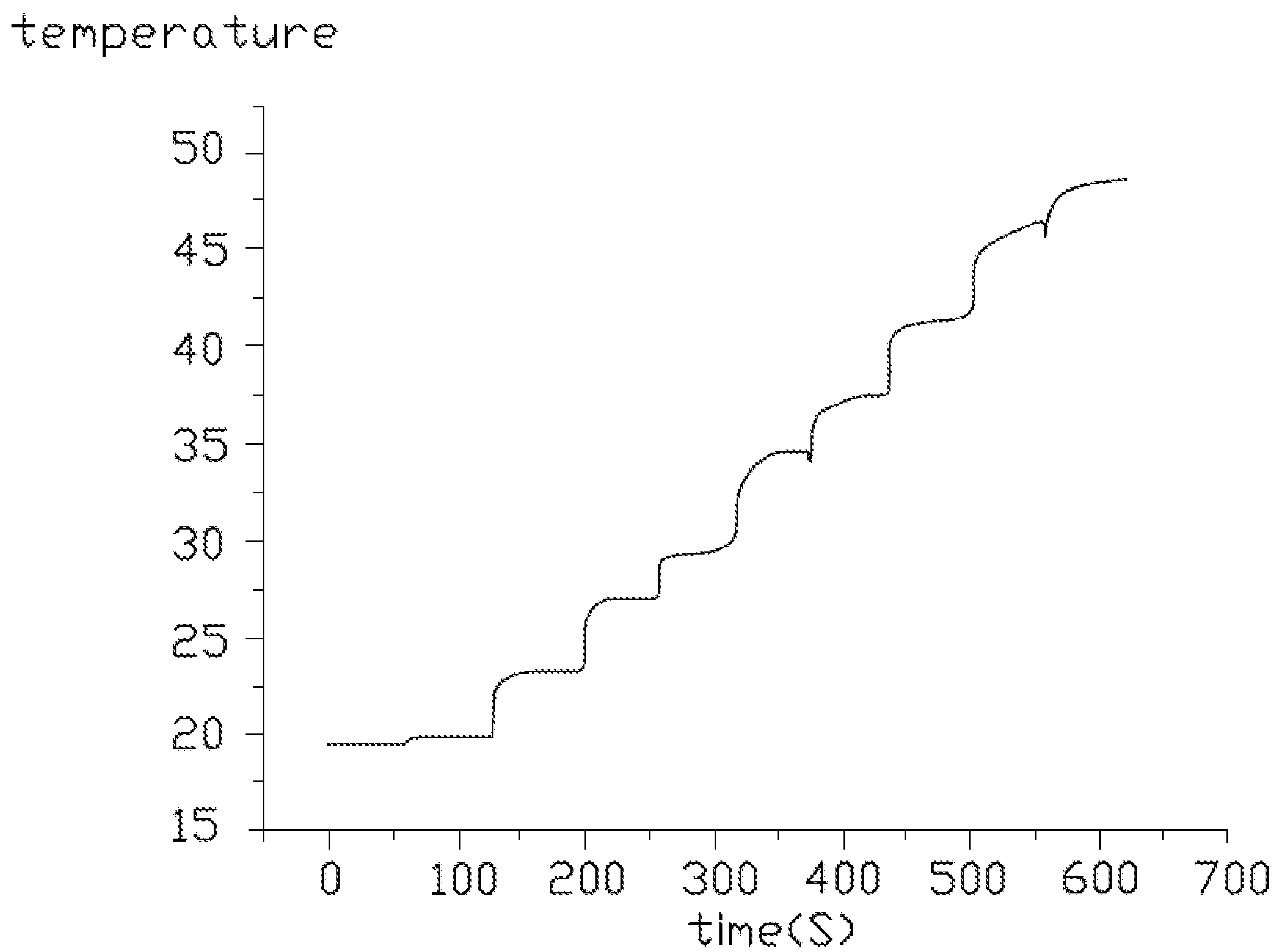
temperature
50
45
40
35
30
25
20
15
0
100
200
300
400
500
600
700
time(S)

FIG. 4

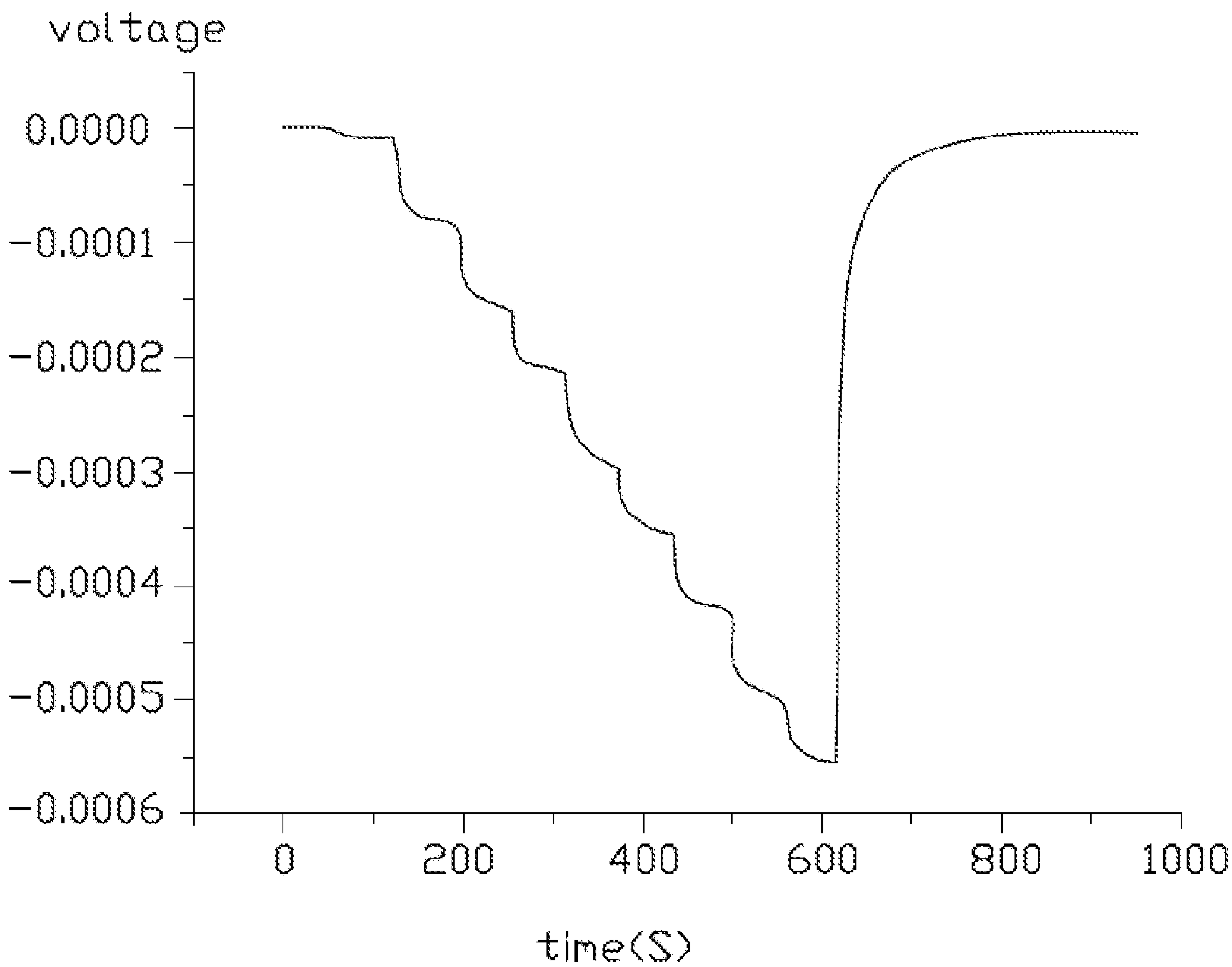
voltage
0.0000
-0.0001
-0.0002
-0.0003
-0.0004
-0.0005
-0.0006
0
200
400
600
800
1000
time(S)

FIG. 5

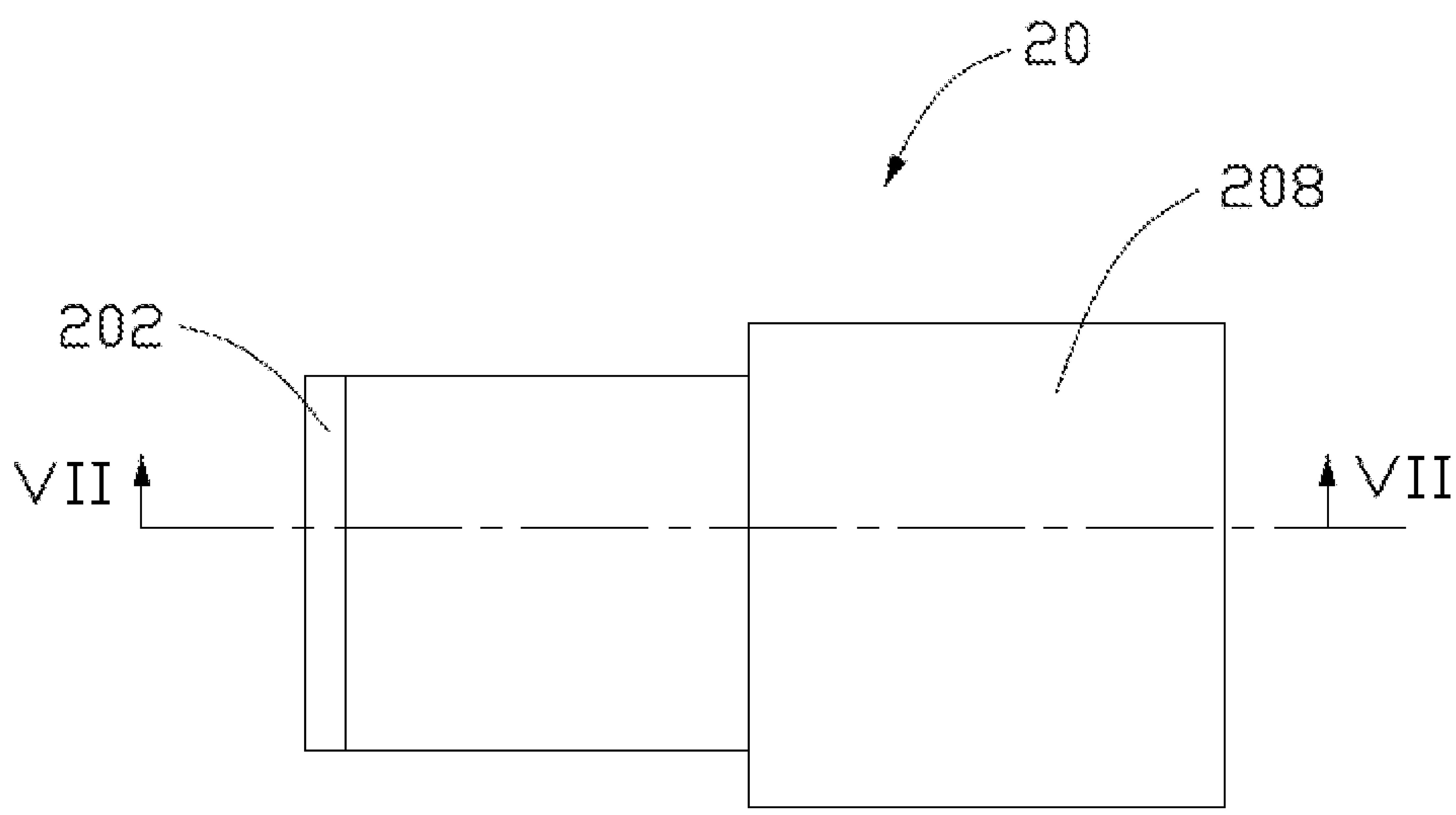

FIG. 6

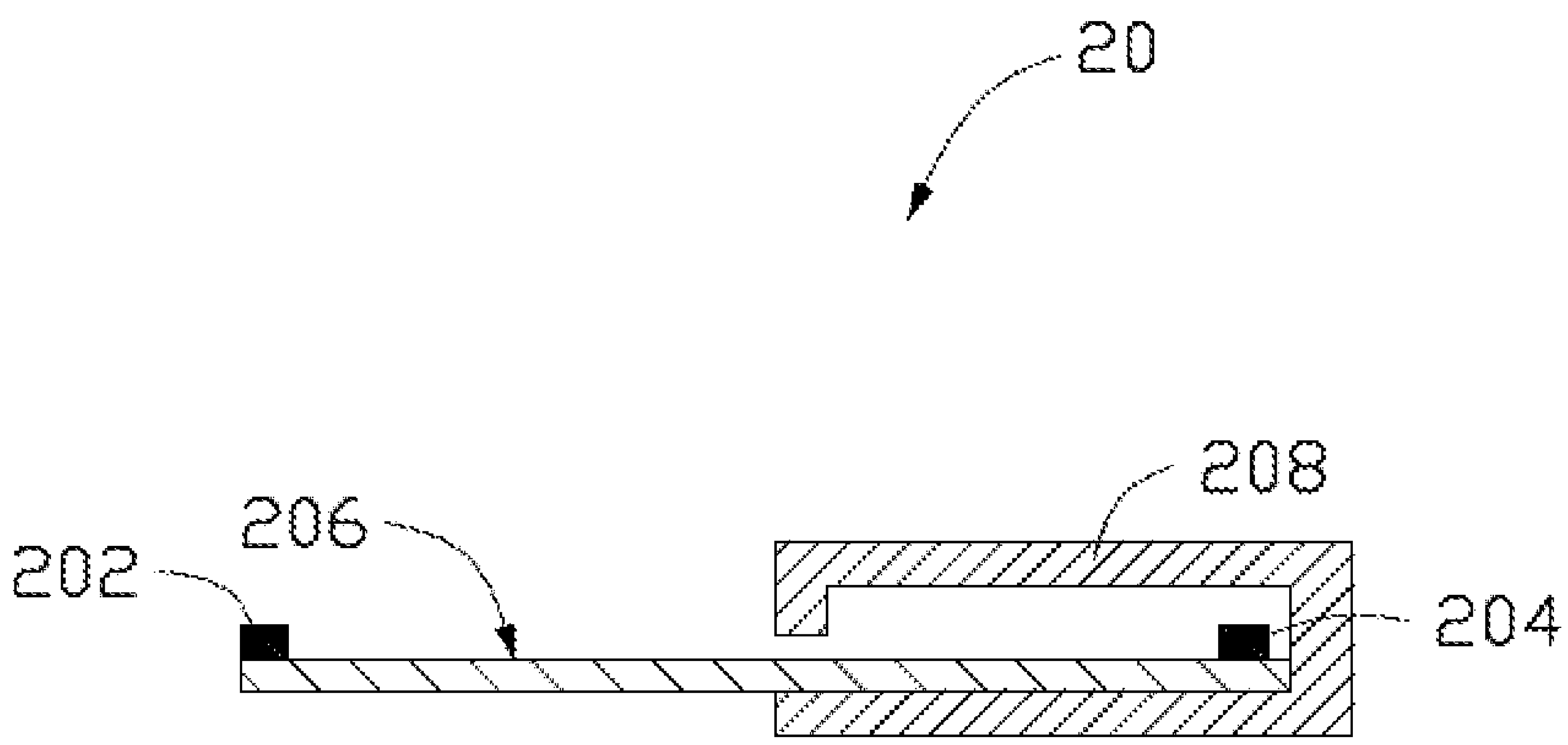

FIG. 7

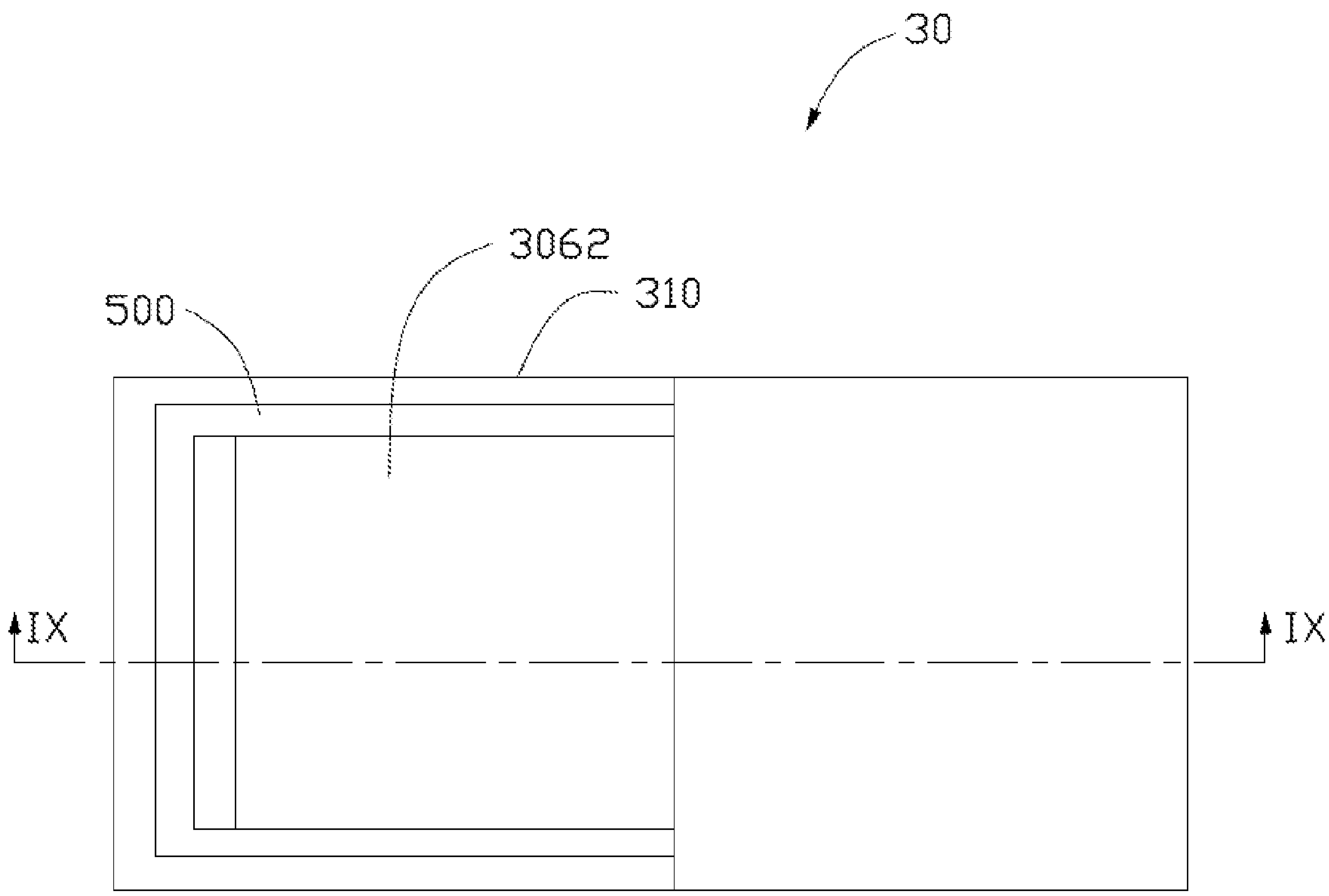

FIG. 8

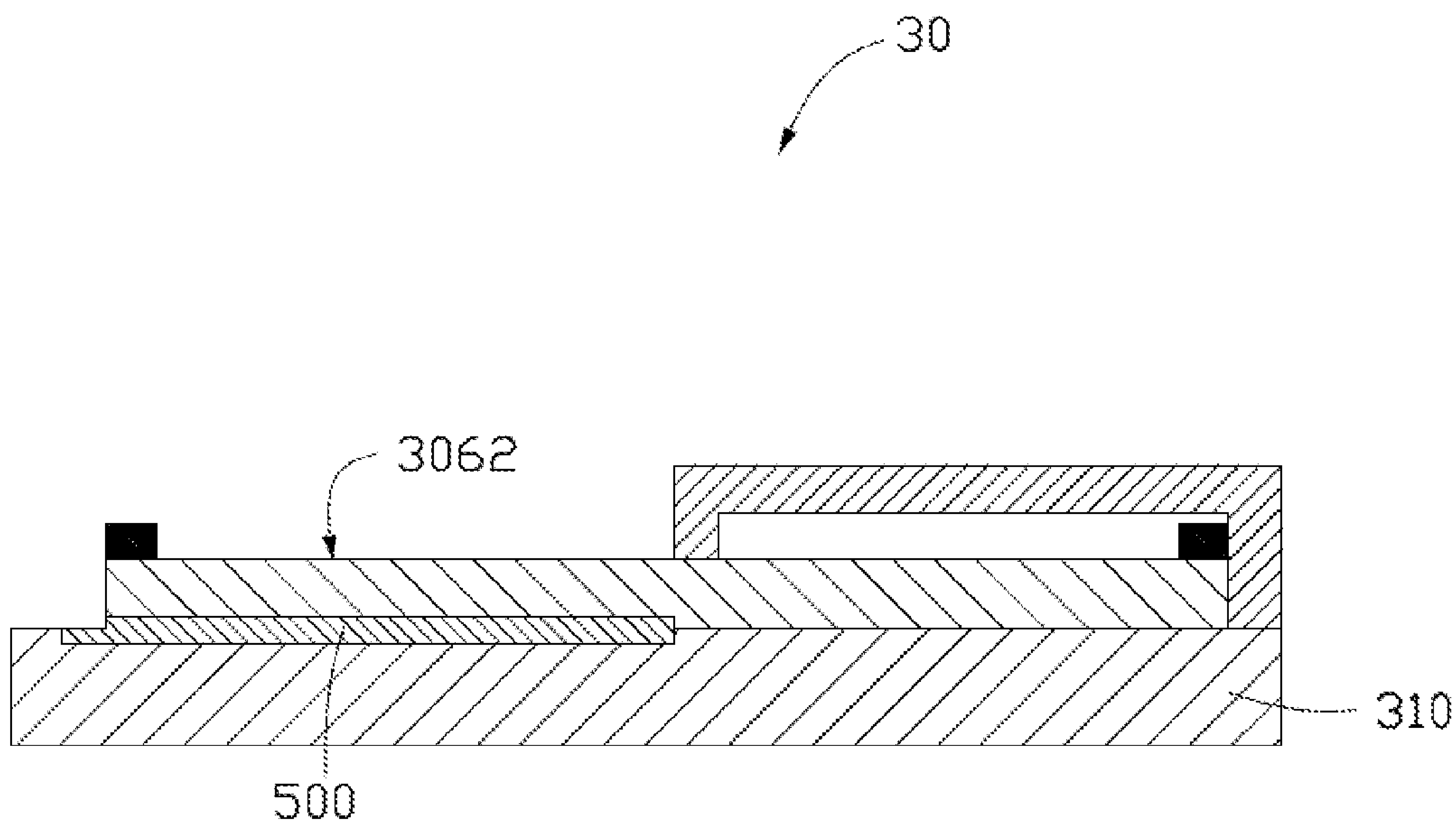

FIG. 9

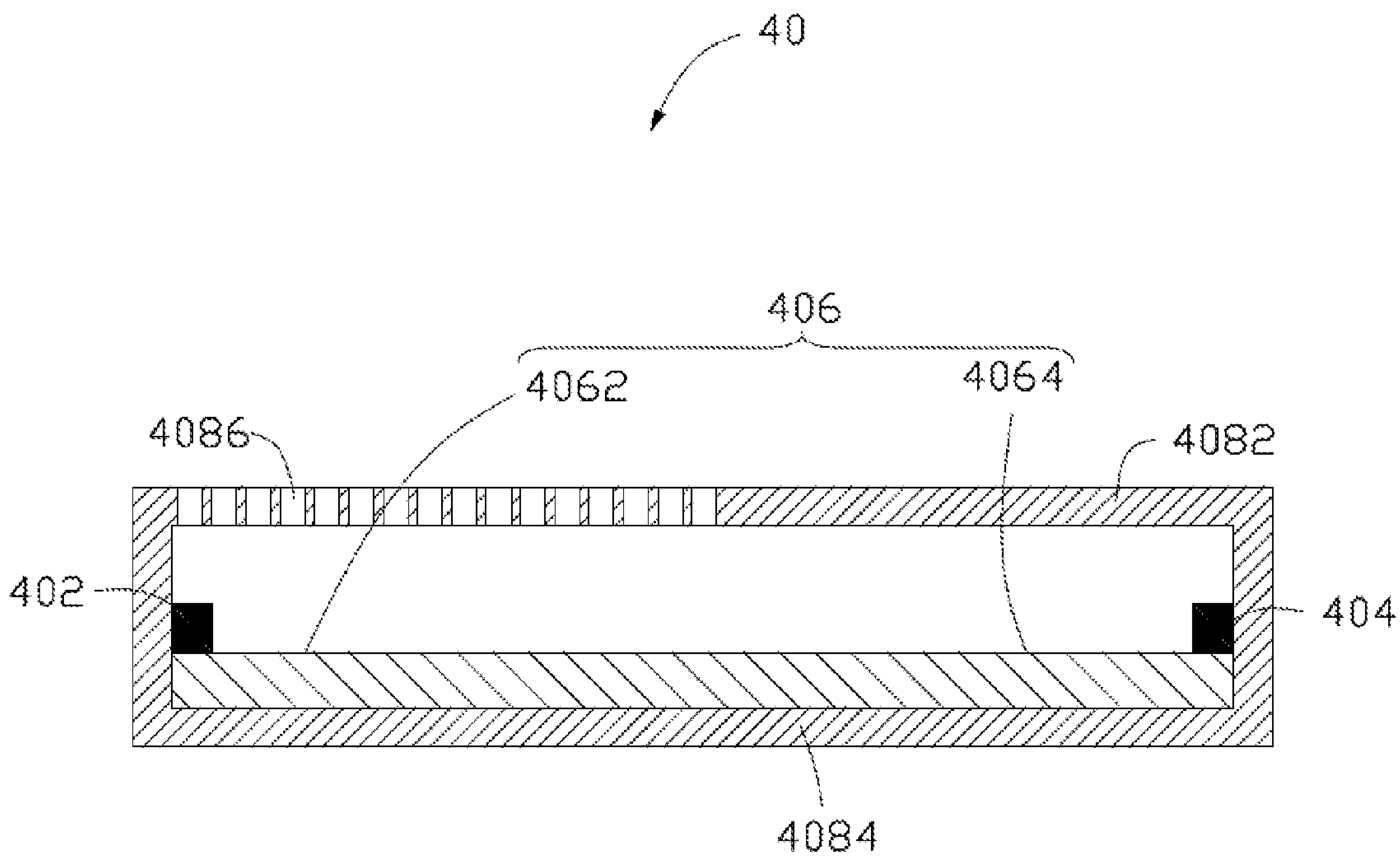

FIG. 10

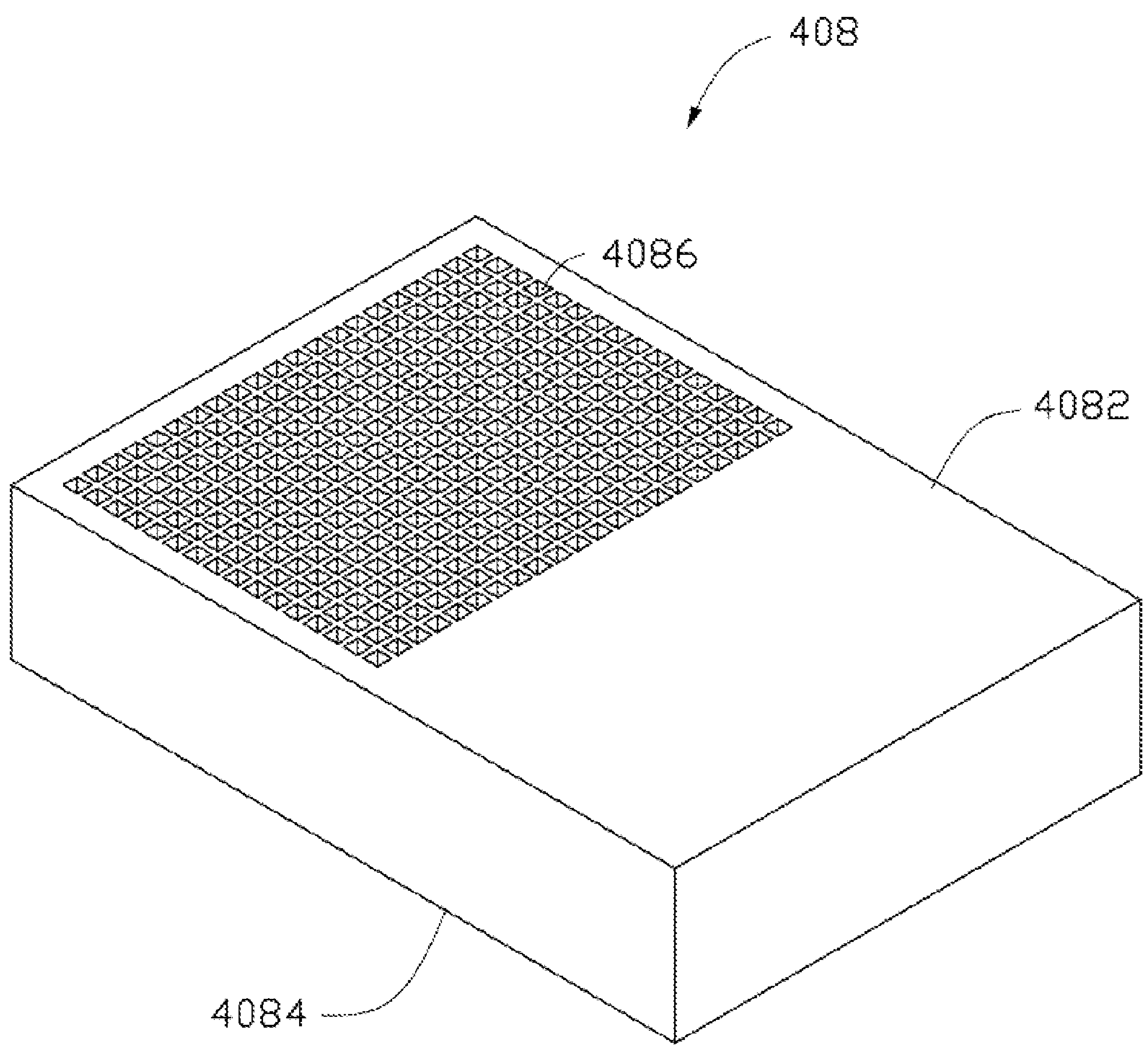

FIG. 11

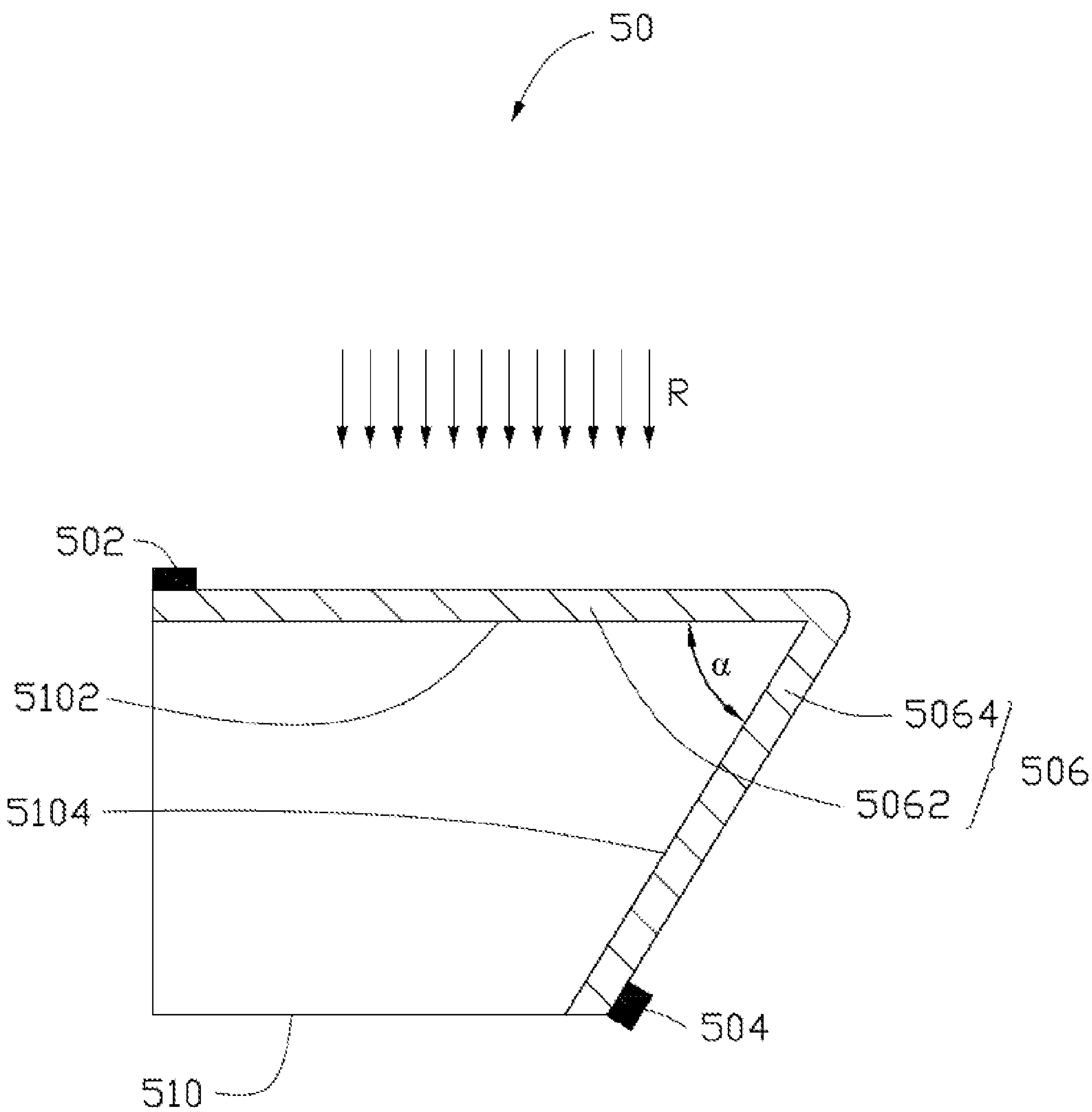

FIG. 12

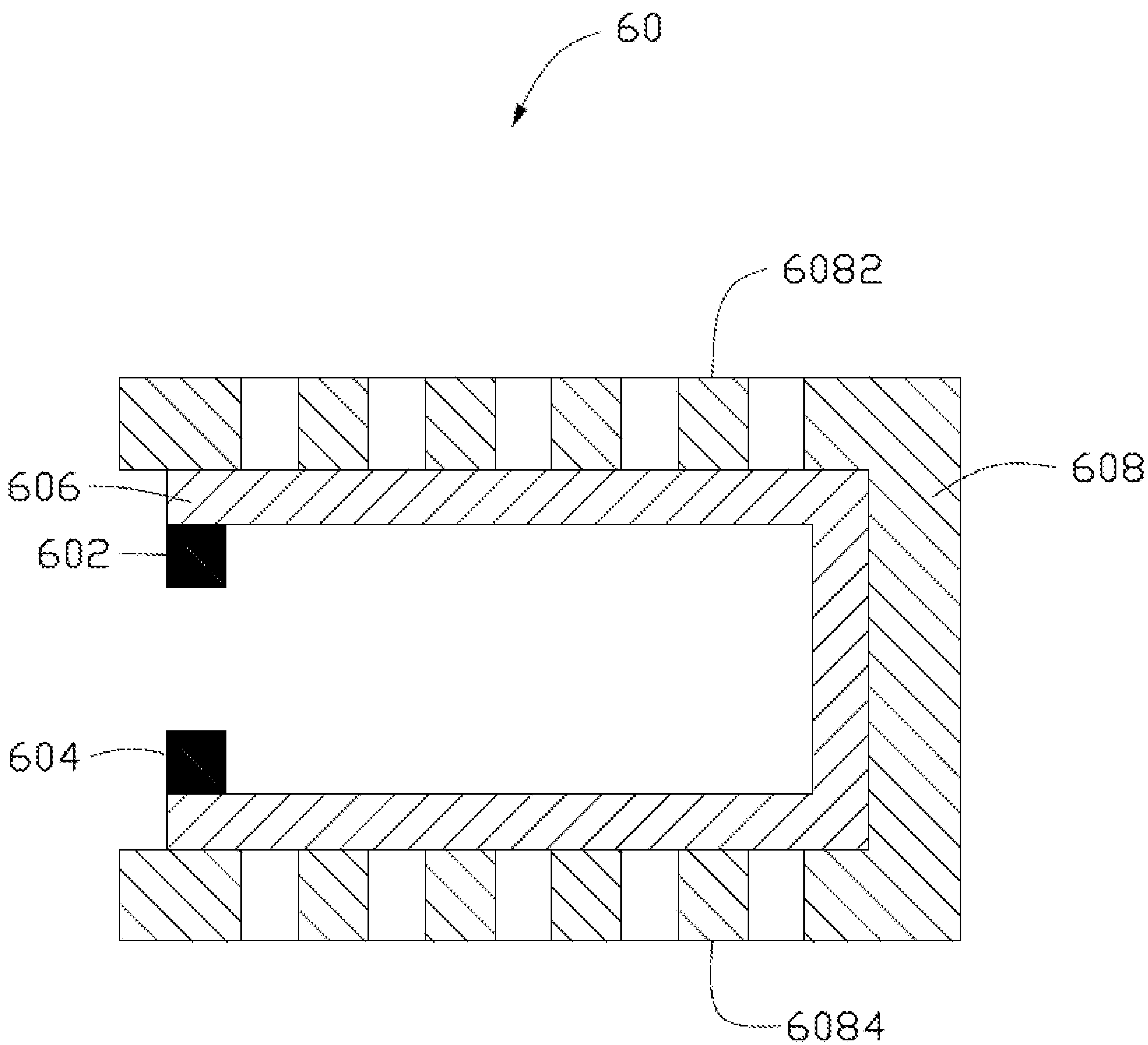

FIG. 13

INFRARED DETECTOR

RELATED APPLICATIONS

This application claims all benefits accruing under 35 U.S.C. §119 from China Patent Application No. 201010210121.0, filed on Jun. 25, 2010 in the China Intellectual Property Office, the contents of which are hereby incorporated by reference. The application is also related to application Ser. No. 12/876,357 entitled, "PHOTOELECTRIC CELL," filed Sep. 7, 2010.

BACKGROUND

1. Technical Field

The present disclosure generally relates to infrared detectors.

2. Description of Related Art

Infrared detectors are used to detect infrared which are not visible to humans. Infrared detectors are used in the medical field, mine detecting field, military affairs, and everyday life.

Infrared detectors can be divided into active infrared detectors and passive infrared detectors according to their working principles and structures. An active infrared detector includes an infrared producing device, an infrared receiving device, and a warning device. When humans, animals or other things pass through the infrared produced by the infrared producing device, the energy of the infrared will change, and the infrared receive device can detect a change of the energy and activate the warning device. Passive infrared detectors do not produce infrared. Instead, the passive infrared detector detects the energy of the infrared signals when infrared irradiates the device. An infrared detector, whether active or passive, should include a detecting element sensitive to infrared. The conventional detecting element uses the photoelectric effect to change infrared into electric signals, and the infrared signals are detected by detecting the electric signals. However, due to the low efficiency of the photoelectric effect, the infrared detected must have enough intensity. As such, the conventional infrared detectors have low sensitivity.

What is needed, therefore, is an infrared detector based on carbon nanotubes that can overcome the above-described shortcomings.

BRIEF DESCRIPTION OF THE DRAWINGS

Many aspects of the embodiments can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale, the emphasis instead being placed upon clearly illustrating the principles of the embodiments. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

FIG. **1** is a schematic view of one embodiment of an infrared detector.

FIG. **2** is a schematic, section view along II-II of the infrared detector in FIG. **1**.

FIG. **2**A shows a scanning electron microscope (SEM) image of a drawn carbon nanotube film.

FIG. **2**B shows an SEM image of a flocculated carbon nanotube film.

FIG. **3** is a schematic view of the infrared detector of FIG. **1** in a working state.

FIG. **4** is a chart showing the relationship between the irradiating area temperature and the infrared irradiating time.

FIG. **5** is a chart showing the relationship between a voltage between the first electrode and the second electrode and the infrared irradiating time.

FIG. **6** is a schematic view of another embodiment of an infrared detector.

FIG. **7** is a schematic, section view along VII-VII of the infrared detector in FIG. **6**.

FIG. **8** is a schematic view of yet another embodiment of an infrared detector.

FIG. **9** is a schematic, section view along IX-IX of the infrared detector in FIG. **8**.

FIG. **10** is a schematic side section view of still another embodiment of an infrared detector.

FIG. **11** is a schematic view of the covering structure of the infrared detector in FIG. **10**.

FIG. **12** is a schematic view of still yet another embodiment of an infrared detector.

FIG. **13** is a schematic view of one embodiment of an infrared detector.

DETAILED DESCRIPTION

The disclosure is illustrated by way of example and not by way of limitation in the figures of the accompanying drawings in which like references indicate similar elements. It should be noted that references to "an" or "one" embodiment in this disclosure are not necessarily to the same embodiment, and such references mean at least one.

Referring to FIGS. **1** and **2**, an infrared detector **10** of one embodiment includes a first electrode **102**, a second electrode **104**, a detecting element **106**, and a covering structure **108**. The first electrode **102** and the second electrode **104** are disposed on two opposite ends of the detecting element **106** and are electrically connected with the detecting element **106**. The covering structure **108** covers part of the detecting element **106**. The infrared detector **10** further includes a substrate **110**, with the detecting element **106** disposed on a surface of the substrate **110**.

The substrate **110** is used to support the detecting element **106**. If the detecting element **106** is self-standing, the substrate **110** can be omitted. A material of the substrate **110** can be dielectric materials, such as glass, ceramic, polymer, and wood. The substrate **110** can also be made of conductive materials coated with dielectric materials. In this embodiment, the substrate **110** does not absorb infrared or absorbs little infrared. A thickness of the substrate **110** can be in a range from about 1 millimeter to about 2 centimeters. In one embodiment according to FIG. **1**, the substrate **110** is a square ceramic sheet of about 5 millimeters thick.

The detecting element **106** is divided into an absorbing part **1062** and a non-absorbing part **1064**. The covering structure **108** covers the non-absorbing part **1064**. The absorbing part **1062** is used to absorb infrared irradiating on the infrared detector **10**. The non-absorbing part **1064** should not absorb the infrared. A temperature of the absorbing part **1062** increases after absorbing the infrared. Thus, a temperature difference exists between the absorbing part **1062** and the non-absorbing part **1064**. A material of the detecting element **106** should have a high thermoelectric transfer coefficient. The detecting element **106** has a planar structure. The planar structure can be a porous planar structure, such as a net structure. The detecting element **106** can be a carbon nanotube layer. The carbon nanotube layer can be planar or convex. The carbon nanotube layer can be a freestanding structure, that is, the carbon nanotube layer can be supported by itself without a substrate. For example, if at least one point of the carbon nanotube layer is held, the entire carbon nanotube layer can be lifted without being destroyed. The carbon nanotube layer includes a number of carbon nanotubes disposed uniformly and joined by Van der Waals attractive force therebetween. The carbon nanotubes can be single-walled carbon nanotubes, double-walled carbon nanotubes, multi-walled carbon nanotubes, or combination thereof. In this embodiment, the carbon nanotubes are single-walled carbon nanotubes. The carbon nanotube layer can be a substantially pure structure of carbon nanotubes, with few impurities. The carbon nanotubes can be used to form many different structures and provide a large specific surface area. The heat capacity per unit area of the carbon nanotube layer can be less than about 2×10^{-4} J/m^2*K. In one embodiment, the heat capacity per unit area of the carbon nanotube layer is less than or equal to about 1.7×10^{-6} J/m^2*K.

The carbon nanotubes in the carbon nanotube layer can be orderly or disorderly arranged. The term 'disordered carbon nanotube layer' refers to a structure where the carbon nanotubes are arranged along different directions, and the aligning directions of the carbon nanotubes are random. The number of the carbon nanotubes arranged along each different direction can be almost the same (e.g. uniformly disordered). The disordered carbon nanotube layer can be isotropic, namely the carbon nanotube layer has properties identical in all directions of the carbon nanotube layer. The carbon nanotubes in the disordered carbon nanotube layer can be entangled with each other.

The term 'ordered carbon nanotube layer' refers to a structure where the carbon nanotubes are arranged in a consistently systematic manner, e.g., the carbon nanotubes are arranged approximately along a same direction and/or have two or more sections within each of which the carbon nanotubes are arranged approximately along a same direction (different sections can have different directions). The carbon nanotubes in the carbon nanotube layer can be single-walled, double-walled, and/or multi-walled carbon nanotubes. In this embodiment, the carbon nanotube layer is a substantially pure structure of single-walled carbon nanotubes.

The carbon nanotube layer can be a film structure with a thickness ranging from about 100 nanometers (nm) to about 5 mm. The carbon nanotube layer can include at least one carbon nanotube film.

In one embodiment, the carbon nanotube film is a drawn carbon nanotube film. A film can be drawn from a carbon nanotube array to obtain a drawn carbon nanotube film. Referring to FIG. **2**A, the drawn carbon nanotube film includes a number of successive and oriented carbon nanotubes joined end-to-end by Van der Waals attractive force therebetween. The drawn carbon nanotube film is a free-standing film. Each drawn carbon nanotube film includes a number of successively oriented carbon nanotube segments joined end-to-end by Van der Waals attractive force therebetween. Each carbon nanotube segment includes a number of carbon nanotubes substantially parallel to each other, and joined by Van der Waals attractive force therebetween. Some variations can occur in the drawn carbon nanotube film. The carbon nanotubes in the drawn carbon nanotube film are oriented along a preferred orientation. The carbon nanotube film can be treated with an organic solvent to increase the mechanical strength and toughness of the carbon nanotube film and reduce the coefficient of friction of the carbon nanotube film. The thickness of the carbon nanotube film can range from about 0.5 nm to about 100 μm.

The carbon nanotube layer of the detecting element **106** can include at least two stacked carbon nanotube films. In other embodiments, the carbon nanotube layer can include two or more coplanar carbon nanotube films, and can include layers of coplanar carbon nanotube films. Additionally, if the carbon nanotubes in the carbon nanotube film are aligned along one preferred orientation (e.g., the drawn carbon nanotube film), an angle can exist between the orientations of the carbon nanotubes in adjacent films, whether stacked or adjacent. Adjacent carbon nanotube films can be joined only by the Van der Waals attractive force therebetween. The number of the layers of the carbon nanotube films is not limited. The thicker the carbon nanotube layer, the smaller the specific surface area. An angle between the aligned directions of the carbon nanotubes in two adjacent carbon nanotube films can range from about 0 degrees to about 90 degrees. If the angle between the aligned directions of the carbon nanotubes in adjacent carbon nanotube films is larger than 0 degrees, the carbon nanotubes in the detecting element **106** define a microporous structure. The carbon nanotube layer in an embodiment employing these films will have a number of micropores. Stacking the carbon nanotube films will also add to the structural integrity of the carbon nanotube layer.

In other embodiments, the carbon nanotube film can be a flocculated carbon nanotube film. Referring to FIG. **2**B, the flocculated carbon nanotube film can include a number of long, curved, disordered carbon nanotubes entangled with each other. Furthermore, the flocculated carbon nanotube film can be isotropic. The carbon nanotubes can be substantially uniformly dispersed in the carbon nanotube film. Adjacent carbon nanotubes are acted upon by Van der Waals attractive force to obtain an entangled structure with micropores defined therein. It is noteworthy that the flocculated carbon nanotube film is very porous. Sizes of the micropores can be less than about 10 μm. The porous nature of the flocculated carbon nanotube film will increase the specific surface area of the carbon nanotube layer. Further, due to the carbon nanotubes in the carbon nanotube layer being entangled with each other, the carbon nanotube layer employing the flocculated carbon nanotube film has excellent durability, and can be fashioned into desired shapes with a low risk to the integrity of the carbon nanotube layer. The thickness of the flocculated carbon nanotube film can range from about 0.5 nm to about 1 mm.

In other embodiments, the carbon nanotube film can be a pressed carbon nanotube film. The pressed carbon nanotube film can be a free-standing carbon nanotube film. The carbon nanotubes in the pressed carbon nanotube film are arranged along a same direction or along different directions. The carbon nanotubes in the pressed carbon nanotube film can rest upon each other. Adjacent carbon nanotubes are attracted to each other and are joined by Van der Waals attractive force. An angle between a primary alignment direction of the carbon nanotubes and a surface of the pressed carbon nanotube film is about 0 degrees to approximately 15 degrees. The greater the pressure applied, the smaller the angle obtained. If the carbon nanotubes in the pressed carbon nanotube film are arranged along different directions, the carbon nanotube layer can be isotropic. Here, "isotropic" means the carbon nanotube film has properties identical in all directions substantially parallel to a surface of the carbon nanotube film. The thickness of the pressed carbon nanotube film ranges from about 0.5 nm to about 1 mm.

Because the heat capacity of the carbon nanotube layer is very low, the temperature of the detecting element **106** can rise and fall quickly, and has a high heating speed response. Further, because the carbon nanotube has a large specific surface area, the carbon nanotube layer with a number of carbon nanotubes has a larger specific surface area and a high infrared absorbing efficiency.

The first electrode **102** and the second electrode **104** can be separately disposed on two opposite ends of the detecting element **106**. The detecting element **106** includes a first end (not labeled) and a second end (not labeled) opposite with the first end. The first end is in the absorbing part **1062**, the second end is in the non-absorbing part **1064**. The first electrode **102** is electrically connected with the first end, and the second electrode **104** is electrically connected with the second end. The first electrode **102** is disposed on the absorbing part **1062**, and the second electrode **104** is disposed on the non-absorbing part **1064**. The first electrode **102** and the second electrode **104** are made of conductive material. The shapes of the first electrode **102** and the second electrode **104** can be wire-shaped or bar-shaped. The cross sectional shape of the first electrode **102** and the second electrode **104** can be round, square, trapezium, triangular, or polygonal. The thickness of the first electrode **102** and the second electrode **104** can be any size, depending on the design, and can be about 1 micrometer to about 5 millimeters. In one embodiment, if the detecting element **106** includes the carbon nanotube layer having a number of carbon nanotubes arranged in a same direction, the axes of the carbon nanotubes can be substantially perpendicular to the first electrode **102** and the second electrode **104**. A material of the first electrode **102** and the second electrode **104** can be metal, conductive polymer, or ITO.

The covering structure **108** is configured to cover the non-absorbing part **1064**, so that the infrared cannot be absorbed by the non-absorbing part **1064**. The material of the covering structure **108** can be conductive or insulated. The electrically conductive material can be metal or alloy. The metal can be copper, aluminum, or titanium. The insulated material can be resin, ceramic, plastic, or wood. The thickness of the covering structure **108** can range from about 0.5 μm to about 2 mm. If the material of the covering structure **108** is insulated, the covering structure **108** can be directly disposed on a surface of the detecting element **106**. If the covering structure **108** is conductive, the covering structure **108** should be insulated from the detecting element **106**. The covering structure **108** can be disposed above the detecting element **106** and apart from the detecting element **106**.

The absorbing part **1062** and the non-absorbing part **1064** are two different parts of the detecting element **106** divided by the covering structure **108**. In the working state of the infrared detector **10**, the absorbing part **1062** absorbs infrared, and the non-absorbing part **1064** is insulated from the infrared. In one embodiment according to FIG. **2**, the absorbing part **1062** is not covered by the covering structure **108** and is able to absorb infrared when the infrared irradiates on the infrared detector **10**. The non-absorbing part **1064** is covered by the covering structure **108** and is not able to absorb infrared when the infrared irradiates on the infrared detector **10**. An area ratio between the absorbing part **1062** and the non-absorbing part **1064** can be in a range from about 1:2 to about 2:1. In one embodiment, the area ratio between the absorbing part **1062** and the non-absorbing part **1064** is about 3:2.

The infrared detector **10** can further include a first lead wire (not shown) and a second lead wire (not shown). The first lead wire is electrically connected with the first electrode **102**, and the second lead wire is electrically connected with the second electrode **104**. The first lead wire can facilitate the first electrode **102** electrically connected with a power source the second lead wire can facilitate the second electrode **104** electrically connected with the power source.

The infrared detector **10** can further include an ammeter **112** and a voltmeter **114**. The ammeter **112** and the voltmeter **114** are connected in series with the first electrode **102** and the second electrode **104**. The voltmeter **114** is configured to test the voltage between the first electrode **102** and the second electrode **104**. The ammeter **112** is configured to test the electric current of the return circuit composed of the first electrode **102**, the second electrode **104**, and the detecting element **106**.

Referring to FIG. **3**, the working principle of the infrared detector **10** is described here. When the infrared R is irradiating on the infrared detector **10**, the absorbing part **1062** of the detecting element **106** absorbs the infrared R, and a temperature of the absorbing part **1062** increases. However, the non-absorbing part **1064** is covered by the covering structure **108** and cannot absorb the infrared. As such, there is a temperature difference between the first end and the second end of the detecting element **106**. Because of a thermoelectric effect, a voltage difference exists between the first electrode **102** and the second electrode **104**. The value of the voltage is related to the intensity of the infrared R. As such, the infrared detector can detect the infrared R and the intensity of the infrared R.

Referring to FIG. **4**, the infrared detector **10** is alternatively exposed to ten different infrared energy densities for about 100 seconds each. The energy densities are 5.709 mW/cm^2, 25.394 mW/cm^2, 45.079 mW/cm^2, 64.764 mW/cm^2, 84.449 mW/cm^2, 104.134 mW/cm^2, 123.819 mW/cm^2, 143.504 mW/cm^2, 163.189 mW/cm^2. In addition, the temperature of the first end **1066** of the detecting element **106** changes quickly according to the infrared energy density. FIG. **5** shows the voltage differences between the first electrode **102** and the second electrode **104** from the ten different infrared energy densities. When the energy density of the infrared changes, the voltage difference between the first electrode **102** and the second electrode **104** changes quickly and accordingly. A relative large voltage difference between the first electrode **102** and the second electrode **104** can be produced under low infrared energy density. As such, the infrared detector **10** has a high sensitivity.

The infrared detector **10** disclosed above has numerous advantages. Firstly, the infrared detector **10** changes the infrared energy into an electrical signal based on the thermoelectric effect. Infrared with low energy density can be detected. Even low energy density infrared can cause a temperature difference between the first end and the second end. Thus, the infrared detector **10** has high sensitivity. Secondly, because the detecting element **106** includes a carbon nanotube layer, and carbon nanotubes are ideal black bodies, the detecting element **106** has high infrared absorbing efficiency, and accordingly the infrared detector **10** has high infrared absorbing efficiency. Lastly, the carbon nanotube layer, especially a carbon nanotube layer having a pure structure of single-walled carbon nanotubes, has high thermoelectric conversion efficiency, and therefore, the detecting element **106** can detect infrared with low energy density.

Referring to FIGS. **6** and **7**, an infrared detector **20** another embodiment includes a first electrode **202**, a second electrode **204**, a detecting element **206**, and a covering structure **208**. The first electrode **202** and the second electrode **204** are disposed on opposite ends of the detecting element **206** and are electrically connected with the detecting element **206**. The covering structure **208** covers part of the detecting element **206**.

The covering structure **208** is a U-shaped frame including a first covering sheet and a second covering sheet substantially parallel with each other. The first covering sheet and the second covering sheet define a hollow space. Part of the detecting element **206** is disposed on a surface of the second covering sheet and in the hollow space. Another part of the detecting element **206** is located outside of the covering structure **208**. The first covering sheet covers the part disposed in the hollow space, and is a non-absorbing part (not labeled). The other part outside of the covering structure **208** is an absorbing part (not labeled). The absorbing part absorbs infrared, and the non-absorbing part is insulated from the infrared.

Other characteristics of the infrared detector **20** are the same as the infrared detector **10** disclosed above.

Referring to FIGS. **8** and **9**, an infrared detector **30** according to still another embodiment includes a reflective layer **500** disposed between the absorbing part **3062** and the substrate **310**. The reflective layer **500** is configured to reflect the heat of the absorbing part **3062** and infrared irradiating on the substrate **310**, so that the absorbing part **3062** has a high absorbing efficiency. A material of the reflective layer **500** can be insulative materials. The insulative materials can be metal oxides, metal salts, or ceramics. The reflective layer **500** can also be IR-reflective material, such as TiO_2—Ag—TiO_2, ZnS—Ag—ZnS, AINO—Ag—AIN, Ta_2O_3—SiO or Nb_2O_3—SiO_2. A thickness of the reflective layer **500** can be in a range from about 20 micrometers to about 500 micrometers.

Other characteristics of the infrared detector **30** are the same as the infrared detector **10** disclosed above.

Referring to FIGS. **10** and **11**, an infrared detector **40** according to yet another embodiment includes a first electrode **402**, a second electrode **404**, a detecting element **406** and a covering structure **408**. The first electrode **402** and the second electrode **404** are disposed on opposite ends of the detecting element **406** and are electrically connected with the detecting element **406**. The covering structure **408** covers part of the detecting element **406**. The detecting element **406** includes an absorbing part **4062** and a non-absorbing part **4064**.

The covering structure **408** is an enclosure defining a hollow space, the detecting element **406** is disposed in the covering structure **408**. The covering structure **408** includes a light-passing region **4086**. The absorbing part **4062** of the detecting element **406** opposes the light-passing region **4086**. The infrared can pass through the light-passing region **4086** and irradiate the absorbing part **4062**. The light-passing region **4086** can define a number of through holes. Alternatively, the light-passing region **4086** can be transparent. A shape of the covering structure **408** is not limited, and can be cylindrical, cubical, or spherical. In one embodiment according to FIGS. **10** and **11**, the covering structure **408** has a cube structure. The covering structure **408** includes an upper sheet **4082**, a lower sheet **4084**, and four side sheets (not labeled). The detecting element **406** is disposed on a surface of the lower sheet **4084**. The light-passing region **4086** is defined on the upper sheet **4082** and includes a number of through holes. The light-passing region **4086** has a net structure.

Other characteristics of the infrared detector **40** are the same as the infrared detector **10** disclosed above.

Referring to FIG. **12**, an infrared detector **50** according to yet another embodiment includes a first electrode **502**, a second electrode **504**, and a detecting element **506**. The first electrode **502** and the second electrode **504** are disposed on opposite ends of the detecting element **506** and are electrically connected with the detecting element **506**. The detecting element **506** includes an absorbing part **5062** and a non-absorbing part **5064**.

The infrared detector **50** further includes an insulated structure **510**. The insulated structure **510** includes a first surface **5102** and a second surface **5104**. An angle α existing between the first surface **5102** and the second surface **5104** is less than 90 degrees. The first surface **5102** and the second surface **5104** can be two opposite surfaces of the insulated structure **510**. The absorbing part **5062** is disposed on the first surface **5102**, and the non-absorbing part **5064** is disposed on the second surface **5104**. As such, the detecting element **506** is curved, and an angle between the absorbing part **5062** and the non-absorbing part **5064** is less than 90 degrees. When an infrared R is irradiating on the absorbing part **5062**, the non-absorbing part **5064** cannot be irradiated by the infrared R because the angle between the absorbing part **5062** and the non-absorbing part **5064** is less than 90 degrees.

Other characteristics of the infrared detector **50** are the same as the infrared detector **10** disclosed above.

Referring to FIG. **13**, an infrared detector **60** according to still yet another embodiment includes a first electrode **602**, a second electrode **604**, a detecting element **606**, and a covering structure **608**. The first electrode **602** and the second electrode **604** are disposed on two opposite ends of the detecting element **606** and are electrically connected with the detecting element **606**. The covering structure **608** covers part of the detecting element **606**.

The covering structure **608** is an enclosure defining a hollow space, and the detecting element **606** is disposed in the covering structure **608**. The covering structure **608** includes an upper sheet **6082** and a lower sheet **6084** opposite to the upper sheet **6082**. The upper sheet **6082** includes a first surface (not labeled), the lower sheet **6084** includes a second surface (not labeled), and the first surface opposes the second surface. The detecting element **606** is curved and is disposed on the first surface and the second surface. The upper sheet **6082** includes a number of through holes, and the lower sheet **6084** includes a number of through holes. In one embodiment according to FIG. **13**, the covering structure **608** has a cube structure, and the upper sheet **6082** is substantially parallel with the lower sheet **6084**.

In use, if infrared irradiates on the upper sheet **6082**, because the upper sheet **6082** includes a number of through holes, the part of the detecting element **606** disposed on the first surface is able to absorb the infrared, and used as an absorbing part, and the other part of the detecting element **606** is the non-absorbing part. When the infrared irradiates on the lower sheet **6084**, because the lower sheet **6084** includes a number of through holes, the part of the detecting element **606** disposed on the second surface is able to absorb the infrared and is used as an absorbing part, and the other part of the detecting element **606** is the non-absorbing part. As such, the infrared detector **60** disclosed here can detect infrared from different directions.

Other characteristics of the infrared detector **60** are the same as the infrared detector **10** disclosed above.

It is to be understood that the above-described embodiments are intended to illustrate rather than limit the present disclosure. Variations may be made to the embodiments without departing from the spirit of the disclosure as claimed. It is understood that any element of any one embodiment is considered to be disclosed to be incorporated with any other embodiment. The above-described embodiments illustrate the scope of the disclosure but do not restrict the scope of the disclosure.

What claimed is:

1. An infrared detector comprising:
- a detecting element comprising a carbon nanotube layer divided into an absorbing part and a non-absorbing part, a first end located in the absorbing part, and a second end located in the non-absorbing part, wherein the absorbing part is configured to absorb infrared, and the carbon nanotube layer is a free-standing and continuous structure;
- a first electrode electrically connected with the first end;
- a second electrode electrically connected with the second end; and
- a covering structure covering the non-absorbing part, to prevent the non-absorbing part from absorbing infrared, and exposing the absorbing part; wherein the absorbing part is exposed through a plurality of through holes spaced from each other.

2. The infrared detector of claim **1**, wherein the carbon nanotube layer comprises a plurality of carbon nanotubes disposed uniformly.

3. The infrared detector of claim **2**, wherein the carbon nanotube layer is a pure structure of single-walled carbon nanotubes.

4. The infrared detector of claim **2**, wherein a heat capacity per unit area of the carbon nanotube layer structure is less than or equal to about 2×10^{-4} J/cm2*K.

5. The infrared detector of claim **1**, wherein the covering structure is an enclosure defining a hollow space, and the detecting element is disposed in the covering structure.

6. The infrared detector of claim **5**, wherein the absorbing part of the detecting element faces the plurality of through holes.

7. The infrared detector of claim **1**, wherein an area ratio between the absorbing part and the non-absorbing part is in a range from about 1:2 to about 2:1.

8. An infrared detector comprising:
- a detecting element divided into an absorbing part and a non-absorbing part, wherein the absorbing part is configured to be exposed to a source of infrared and configured to absorb infrared;
- a first electrode electrically connected with the absorbing part;
- a second electrode electrically connected with the non-absorbing part;
- means for sheltering the non-absorbing part from infrared;
- wherein the detecting element comprises a carbon nanotube layer structure, and the carbon nanotube layer is a free-standing and continuous structure, both the absorbing part and the non-absorbing part are part of the carbon nanotube layer; and
- a net structure configured to shelter the absorbing part, the net structure defines a plurality of through holes spaced from each other, and the absorbing part is exposed through the plurality of through holes.

9. The infrared detector of claim **8**, wherein the carbon nanotube layer structure is a pure structure of single-walled carbon nanotubes oriented in a substantially same direction and joined end-to-end by Van der Waals attractive force.

10. The infrared detector of claim **8**, wherein the carbon nanotube layer is a planar structure.

11. An infrared detector comprising:
- a covering structure, wherein the covering structure defines a hollow space, the covering structure comprises an upper sheet and a lower sheet spaced from each other, the upper sheet defines a light-passing region, and the light-passing region defines a plurality of through holes spaced from each other;
- a carbon nanotube layer, wherein the carbon nanotube layer is located on the lower sheet, the carbon nanotube layer is a free-standing and continuous structure and divided into an absorbing part and a non-absorbing part, the absorbing part faces to the light-passing region and configured to absorb infrared through the plurality of through holes, and the non-absorbing part is sheltered by the upper sheet; both the absorbing part and the non-absorbing part are part of the carbon nanotube layer; and
- a first electrode and a second electrode spaced from each other, wherein the first electrode and the second electrode are electrically connected to the carbon nanotube layer.

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